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Road Safety Research in the Perspective of Policy Analysis

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I. Introduction

Point of View

Even the most cursory overview shows the fabric of road safety research to be composed of uncountably many individual strands of activity. There are engineers crashing instrumented cars together, psychologists administering personality tests, statisticians performing regression analyses, physicians assessing human injury and physiological impairment, to name just a few. Much of the research is of high quality; some is not.

Perhaps more telling, however, than the quality of the research upon its ultimate effectiveness is its fragmentation and its lack of focus upon policy questions. We thus find duplication of activities, gaps of research coverage, failure to coordinate complementary endeavors, and concentration upon areas where research success would be unlikely to lead to practical benefit. To a certain extent, this is inevitable and even desirable. If science is to remain creative and original, it cannot be too tightly directed lest a disaffected sterility set in.

We sense, though, that road safety research suffers from the lack of a comprehensive strategy for concentrating upon its final goal of reducing the incidence and severity of accidents. The overviews that do exist are mostly in the form of anthologies which demonstrate the common phenomenon of research ingrown upon itself as limited facets of the overall problem are explored in extraordinary depth while others are ignored. By and large, these accounts do not systematically analyze the research strands in light of their pragmatic purposes, nor do they provide an estimate of opportunities forgone.[1] We argue that the entire tangled skein of safety research needs to be related to a common reference point which will show how the individual research segments interact with each other and how each one individually contributes to the ultimate objectives. It is hoped that the developing discipline of policy analysis can supply this needed perspective.

Summary

This paper has been written as a preliminary sketch to show how policy analysis might enable a broader, more goal-directed outlook for safety research. The research area is, however, so large and so complex that an introductory paper such as this cannot hope to provide a fully adequate basis for the needed overview. We will instead limit our ambition to describe in the first half of this paper methodological and practical difficulties which bound the practical value of safety research. These difficulties include: the multifarious factors underlying accidents, limits to the reliability of controlled experimentation, analytic pitfalls, the temptations of subsystem focus, the frequent lack of effective governmental leverage, and societal considerations of equity.

Having briefly examined these obstacles to effective policy analysis, we will in the second half of the paper discuss the broad strategic guidelines for safety research so that it may--with greatest directness and with minimal waste of time, men, and money--achieve reduction of accident harm. We will recommend that a comprehensive and imaginative approach be adopted to generate, investigate, and evaluate as many as possible public policy levers for bettering the road accident situation. The limits to the improvement that can be achieved through the molding of voluntary individual conduct should be recognized, and a pragmatic, behavioral perspective adopted. Simplicity of proposed governmental actions is a strong selling point. Finally, we urge that safety research be conceived and categorized within the spectrum running from hypothesis generation through hypothesis confirmation, policy experimentation, and policy evaluation. At one end of this spectrum are found the unconstrained and inventive attempts to understand the situation; at the other are rigorous assessments to make certain that policy measures theoretically attributed benefits do in fact achieve what is claimed for them. The taxonomy is designed to show how all strands of safety research should ultimately be focused upon the overriding goal of reducing accident harm.

Policy Analysis

The critical perspective we adopt and urge is that of policy analysis. As a new discipline, the concept of policy analysis is sheathed in an ambiguity that is often used to screen its limitations. Policy analysis is not a magical new tool that can automatically bring rational order out of muddle. It is rather a structured application of common sense whose methods can be and should be clearly spelled out in order that the lay observer may have confidence in its results. The pre-eminent method of policy analysis is the careful delineation and contrast of the inputs and outputs of policy actions. In order to trace complicated policy effects through a series of

mechanisms to their ultimate impact, the special techniques of systems analysis must often be applied.

The personal background of this writer lies within the area of policy analysis--with concentration upon its application to the evaluation of bio-medical research. The shallowness of his experience with safety research requires that this paper not attempt to supply the encompassing overview which we argue is needed. Instead, the paper restricts itself to identifying the obstacles hampering such an overview and to limning the strategic outlines for its provision.

II. Obstacles to Unified Policy Analysis of Road Accidents

The Compounded Factors of an Accident

It is the exceptional accident whose cause can confidently be ascribed to a limited number of factors. Examples might be the accident caused by a car whose steering mechanism suddenly failed or the accident brought about by a drunken driver straying from his driving lane. Even here, however, the single dominant factors are entwined with others. The speeds at which those cars were being driven, the condition of the road surface, the possible existence of an uncrossable median, the reactions of other drivers, and interior car design might all influence the severity of harm resulting from the accidents.

More common, however, are those accidents for which no preeminent cause exists. Consider the case of Driver A following Car B which suddenly slows to make a right turn. Driver A swerves abruptly to avoid a collision. His car slides out of control across the road where it strikes a metal restraining barrier, spins off into the path of oncoming Car C where it is struck. Driver A dies in the ambulance.

In this instance, it is possible that the death would have been avoided:

1) if the reflexes of Driver A had not been dulled by a long day at work, or by the carbon monoxide leak in his passenger compartment[2] or by the beer with his co-workers at the end of the day, or by residual anxiety from an early morning squabble with his wife; or

2) if he had been driving slower or following less closely; or

3) if the bad angle of the sun, or the poor placing of a sign, or the glare reflected from the engine hood had not prevented Driver B from seeing his turn earlier; or

4) if a turn-off lane had obviated the need for sudden braking in traffic; or

5) if the brakes in Car A had not been designed at an awkward angle, or if the tires had been wider[3] or less worn down, or if better design of the brakes had prevented their momentary locking;[4] or

6) if the road barrier had better absorbed the glancing blow from the car instead of repelling it back onto the highway; or

7) if the oncoming Driver C had been more alert; or

8) if Driver A had worn a seatbelt, or had a padded dashboard; or

9) if the ambulance had arrived more quickly at the scene; or if passing motorists had administered prompt first aid.

To assign blame is impossible. Not only did each of the three drivers contribute to the accident but roles also were played by the out-of-sorts wife, the bibulous co-workers, the car manufacturer, the road designer, the engineer who supervised the installation of the barrier, and the ambulance team. The objective of policy analysis is not to assign blame[5] but to identify those factors which can, with greatest cost-effectiveness, be altered to improve the overall accident situation. We will argue below that safety research should be targeted to achieve this: that is should begin with a situational survey to identify accident factors; that it should proceed to generate possible policy measures by which the factors may be modulated or controlled; and that policy measures implemented must finally be evaluated to gauge their impact and their overall social cost.

The Simulator Approach and Its Shortcomings

The intricate interplay of factors underlying accidents together with the frequency of accidents--which socially is excessive but for the researcher is too low to permit observation of accidents as they occur--has led to the development of factor simulators. An ambitious example is the UCLA Driving Simulation Laboratory[6] where motion picture projectors, an automobile interior and on-line computer power are combined to mimic the highway situation. A simpler and more common type of simulation is found in the many trials in which experimental subjects are given increasing doses of alcohol[7]--or are encouraged to become exceedingly tired[8]--in order that their responses and overall driver behavior might be recorded instrumentally and be quantitatively assessed.

The advantages of the simulator approach are:

a) economy--in that situations of interest occur too infrequently in the natural course of events to reward waiting for their occurrence;

b) information access--information on the factors underlying actual accidents may be withheld or distorted by accident participants;

c) safety--simulation of accident-related factors on the highways would not be tolerated; and

d) research rigor--the factors influencing accidents can, in a simulated setting, be controlled to obtain statistically unimpeachable results.[9]

Unfortunately, many factors militate against the utility of the simulator approach:

1) the Hawthorne effect may critically alter the performance of experimental subjects so that they act differently from accident participants;

2) the population of experimental subjects may differ significantly from that of accident participants;

3) the very attempt to control for all factors but the one central to the study excludes the synergistic interactions of factors which may underlie the vast majority of accidents; and

4) the accident itself may represent a rare pathological phenomenon which cannot be induced by laboratory controlled deprivations or inebriations of experimental drivers.

The implication of these shortcomings taken together is a limitation upon the role that simulator experimentation may play in the policy analysis of accidents.

Analytic Traps and Gaps

Since the deficiencies of simulations restrict the amount of useful safety research that may be performed in the laboratory, a natural scientific response is to rely more heavily upon data gathered from experience on the open road. Unfortunately, the drawing of accurate inferences from this data is hampered by a broad spectrum of analytic pitfalls. To illustrate the attendent dangers, we consider first the long-standing analytic problem of identifying the characteristics of drivers particularly prone to accidents.

Types of difficulties encountered include;

a) Naive statistical analysis. In any short period of time, the total number of drivers involved in accidents will constitute but a small fraction of the driving population. Over a longer period of time--if all drivers are at any moment equally likely to have accidents--it is to be expected that by the time thirty per cent of the drivers have had two or more accidents, one third of the drivers will still have had none. Both of these facts are mere statistical results without practical significance. Neither result proves that any group of drivers is a more dangerous subset of the driving population nor does either provide any indication of which drivers will be more likely to have accidents in the future. To distinguish between true accident proneness and such statistical artifacts requires delicate analysis which too often has been forgone.[10]

b) Adjustment for exposure. Still further confounding the attempting identification of the dangerous, accident-repeating driver are the differential amounts of miles driven. Many studies attempting to single out more accident-prone drivers may in fact only be identifying those who drive more.[11] This problem often can be adequately surmounted by taking mileage driven as a proxy for exposure. Pedestrian studies encounter the same problem. One such study[12] recently showed that a large number of adult pedestrians killed in road accidents lacked driver licenses. The explanation could then readily be constructed that persons unfamiliar with the operation of motor vehicles might be less adept at assessing and avoiding the dangers which they pose for pedestrians. The methodology did not, however, rule out the possibility that lack of a driving permit simply leads to more hours of exposure as a pedestrian.

c) Distinguishing true causal effects. With the interweaving of many demographic characteristics, sensitive analysis may be required to pick out true causal factors. Thus in one study[13] of pedestrian fatalities, a linkage was found--even after adjustment for exposure--between hazard and the factors of being foreign-born and without a spouse. The clever analyst would have no problem inventing explanations for these findings. Nevertheless, in this particular study, these linkages were shown to be mere correlates of age: older pedestrians incurred greater hazard per unit exposure while foreign-born and spouseless pedestrians tended to be older. When age was controlled--for instance, by considering foreign-born and native-born pedestrians of the same age--the effects disappeared.

The number of similar factors that can complicate and lead astray even meticulous analysis are many and not subject to comprehensive classification. Examples of other inferential pitfalls that have jeopardized competent research are:

1) Ex post interviews have been designed to discover personality differences between accident participants and demographically matched drivers who had no accidents.[14] Many such interviews revealed no differences --and, in effect, no accident-prone personality. Those interviewers who did could never be certain that the statistically significant personality differences had in fact predated and contributed to the accidents. They may have been induced by the trauma of the accident itself;

2) Any statistical study of all licensed cars may have difficulty adjusting for accident exposure and for the types of drivers who purchase specific types of cars. Any study seeking to prove that certain car types are either more likely to be involved in accidents or more lethal when involved would have to make delicate adjustments for these factors; and

3) Evaluation of driver education has encountered similar types of preselection problems. Thus, while several studies have shown that graduates of driver education classes have significantly fewer accidents, other studies have shown that the population that opts to take driver education courses is significantly different--in terms of exposure and other traits--from that which does not.[15]

The Too Narrow Focus

The systems perspective has been adopted by policy analysis to avoid the prevalent conceptual errors of subsystem optimization. In the area of accident prevention, focusing narrowly upon limited problem aspects might:

a) lead to solutions that would reduce certain factors underlying accidents while simultaneously increasing the likelihood of accidents due to other causes;

b) render attractive policies having the direct effect of reducing accidents yet setting into motion a series of adaptive actions making the net policy impact less desirable than the direct benefits or even, in sum, undesirable;

c) overlook--through concentration on the statistic of accidents per person-mile--the possibilities of achieving the goals of safety through reduction in the demand for travel;

d) reduce accidents at an excessive cost according to prevailing social values; or

e) fail to take into account the operating principles and goals of such other societal systems as the health care system, the legal system, and the urban system which must be carefully coordinated with policies seeking to realize safety in transportation.

As an example of the First case it has occasionally been shown that widening of road shoulders leads to increased accident levels. A priori, this effect is surprising in that broader shoulders should enable recovery from many accidents caused by instances of straying from the road. In fact, the safer road edges may induce generally a more casual and less careful driving attitude leading to more accidents. Broader shoulders might also lead to more risky attempts to pass.

Other hypothetical effects can be imagined. Intermittent stretches of broad-shoulder roads might induce driving laxness that would carry over to parts where the shoulders had not been widened with the result that accident rates would be higher than if the shoulders had in no parts been improved. An effect in the opposite direction that would be difficult to measure would be reduction in anxiety from having safer road shoulders. This lessened anxiety over long trips might reduce driver fatigue and thus indirectly lower the rates of accidents hundreds of miles distant from the improvements.

In many countries, the continued high rates of accidents on roads widened in places to three lanes has led to speculation upon the causes. It had been hoped that the extra lane would allow faster traffic to perform much of its passing in a safe middle lane--thereby reducing the number of accidents and facilitating traffic flow. In fact, accident levels have increased because:

1) the three-lane stretches raise the speed-aspiration levels of drivers who seek to maintain their high speeds on the two-lane roads; and

2) the three-lane stretches increase the number of road discontinuities--known to be vitally linked to accidents. They would, for instance, lead to many accidents caused by hazardous passing at the end of three-lane stretches.

Here also, a primary gain of these road improvements might be reduced driver frustration whose benefits would be lowered accident incidence elsewhere. Such a gain might prove prohibitively difficult to measure.

Taking a still broader perspective it might be the case that all safety improvements have the effect of generating more traffic or higher speeds and ultimately more accidents. The relative constancy of accidents per capita, despite a sharply

declining rate of accidents per vehicle-mile, suggests that such a phenomenon may occur.[17] If traffic behavior in fact follows such a law, then no series of safety improvements would have any substantial effect in reducing road injuries and fatalities. Instead, the gain of safety policy would lie in increasing the number of miles traveled per person while maintaining the same accident rate. Since many people do desire more travel, this might represent a benefit of safety expenditures --if hardly that originally intended.

The demand for travel should itself be analyzed. Many persons may consider travel a desirable end in itself and accidents a necessary if unfortunate accompanying cost. To others, however, travel is a means of attaining an end--a bargain in a store or a seaside vacation. Instead of an objective, the travel per se may be a necessary evil combining discomfort, cost, danger, and loss of time. In such cases, better city or regional planning geared to reduce the need for travel will be an effective contribution to safety and to other societal goals even though the accident rate per vehicle mile is not altered. Integrated transportation planning diverting more persons to modes of mass transit can also enhance overall safety.

The amount of resources appropriately devoted to reducing accident damage depends upon the societal context. It is immediate that marginal monies should not be spent on road improvements when they could achieve in other policy areas--such as medicine--far greater morbidity and mortality savings. Road traffic accidents can generally be reduced in severity and number by lowering speed limits.[18] Nevertheless, this gain is achieved at the cost of lost time which motorists may judge excessive. A society may as a whole prefer a higher speed limit with concomitantly greater risk. More difficult policy problems are raised when one group of drivers is perceived to have a higher frequency of accidents. Even when such a determination has been made, the social value placed on granting virtually all individuals the right to drive may rule out accident reduction through license revocation. It is the task of policy analysis to determine not only all possible ways to reduce the harm caused by road accidents but also to identify the points at which the marginal societal costs of further marginal reductions outweigh the gains.

Such determinations, to be efficient, must take into account the roles played by other social systems intersecting the area of road safety. Thus urban design, delivery of health care services, jurisprudence and law enforcement all affect policies for reducing harm from road accidents, yet all perform also a broad variety of other social functions. It would be shortsighted to formulate governmental actions requiring extensive modification of those systems in neglect of their other goals. Instead, careful interdisciplinary coordination among the systems is necessary to achieve improved road safety with minimal detraction from other social ends.

The Policy Handle

Scientific objectivity in identifying elements underlying accidents must be accompanied by practical judgments upon how alternative factors can be manipulated to achieve effective control of accident damage. Possible policy actions may be rendered ineffectual or impossible to impose by the small number of accidents they would influence, by obstinate public failure to abide by governmental ordinances, by social reluctance to revoke driving rights, and by the immeasurability of accident preconditions.

Many factors suspected to underly accidents have little policy importance due to the small number of accidents in which they play a role. Thus it had been conjectured that diabetics --in being subject to insulin reactions--would pose a greater than average hazard on the road. Investigation has shown, however, that the diabetic condition itself is unlikely to affect as many as one accident in 10,000.[19] The implementation of stricter controls on diabetics would therefore have a minimal impact not justifying such limitations.[20]

Other considerations known to play a role in accidents may not be subject to policy manipulation. Thus, if drivers obstinately refuse to abide by posted speed limits, the policy importance of alterations in those limits becomes negligible.[21] The provision of seat belts as a mandatory item in cars had only a limited effect due to the continuing failure of drivers and passengers to use them. It has recently been shown that additional televised warnings and exhortations to use seat belts have undetectable impact on their usage.[22]

When statistical analysis shows that a group of persons has significantly higher accident rates per unit exposure, social unwillingness to deny driving permission without tangibly justified cause limits the utility of this finding. Even when society feels that justification exists for license revocations, continued driving despite the loss of license reduces the effects of this policy determination.[23]

The supposition that driver fatigue contributes to accidents[24] presents special problems in policy implementation. To a certain extent, societies will condone driving while tired as an inevitable consequence of the work ethic. When excessive fatigue leads to blatant danger, the driver is encouraged to leave the road. This encouragement, however, lacks statutory backing simply because there is no balloon-test for fatigue--i.e. no possible standard of fatigue that would enable a society or its enforcing policemen to determine when a tired driver should be forced from the highways. Similar lack of measurement instruments makes it impossible to prevent the driving of a person whose momentary emotional disturbance constitutes a road hazard.

Equity and Externality

Underlying many of the policy difficulties described above are considerations of social equity. The right to drive a motor vehicle is widely prized and not lightly denied or revoked. Belonging to a demographic class of persons with high accident rates is rarely considered sufficient grounds for denial of license. The exceptions are cases in which physical or mental handicaps constitute lasting impairments to driving capacity. When the handicaps are temporary there may be no reason to deny the right to drive during periods without incapacity. On the other hand, demonstrable responsibility for accidents as well as hazardous driving behavior is usually considered adequate ground for license revocation.

Coming to receive greater explicit attention in safety research is the broader question of externalities. The traditional micro-economic solution to situations displaying externality effects has been implementation of devices enabling their internalization--such as effluent taxes imposed to curb environmental pollution. The inadequacy of such devices in the highway situation has long been evident. The hazardous driver bears the risk of his own death from his behavior but there is no way to make him bear--or internalize--the mortal danger he poses to others.

Similar problems of equity caused by externality considerations are:

a) Exterior car protrusions. Justified in the name of style, such ornamentation as fins constitute hazard for pedestrians struck by even low-speed cars.[25] A rubberized bumper has little benefit for the car owner[26] but instead protects solid objects which the car may encounter. On this basis, bumpers may reasonably be mandated by the government;

b) Car size. Statistics show that occupants of small cars involved in accidents run a greater risk than the occupants of larger cars.[27] If this risk were solely a function of one's own car size, there would be no externality inequity and the factors of size, risk, and cost would be appropriately considered at the time of purchase. Elementary physics, however, points out that the damaged incurred from a head-on collision depends vitally upon the ratio of the weights involved. Purchase of a larger car thus simultaneously protects the purchaser and increases the risk for other cars.[28] This again is an externality effect appropriate for governmental intervention; and

c) Mileage. The number of miles driven gives a rough measure of the hazard which one car creates for others. Along with automotive pollution and the high price of fuel imports, this factor helps to justify central regulation of distances driven.[29]

III. The Prescriptions of Policy Analysis

The Orientation of Policy Analysis

Perhaps the greatest advantage that the policy analyst of the 1970's has over his intrepid counterpart a decade earlier is a sense of what can go wrong. Sophisticated rational analysis divorced from the realities of social systems and human foibles founders upon those obstacles to the implementation of its sweeping solutions. The road accident situation cannot be treated as a phenomenon to be stated in problem terms then solved in ivory tower isolation. This is because: 1) the situation itself is so complex that it never can be fully grasped by even a series of extended descriptions; and 2) interaction with real world phenomena is necessary to insure that theoretical benefits are achieved in practice. Our prescription for better directing safety research therefore is based upon continuing attempts to understand better the myriad factors involved in accidents and upon thorough evaluation of all contemplated or implemented policy measures.

Policy analysis of road traffic accidents begins with an overview of all factors that might cause or contribute to property damage, injury, and death from such accidents. The next step is to formulate actions to combat or to attenuate those specific factors. From these flights of imagination, the analyst retreats to consider questions of practicality. Obstacles and costs to implementation are carefully examined. However important a factor may be to the total body of accidents, it cannot be the focus of policy remediation if the behavior of persons or social units makes it impervious to change or if the cost of the requisite policy is excessive.

The Search for More Effective Policy Levers

In the last decade and a half, the approach of accident analysis has taken on a pragmatic, behavioral perspective. More innovative ways are being sought to correct the human errors and irresponsible actions that lead to accidents. Yet it also is being recognized that the ability of a government to influence human conduct is limited and subject to decreasing marginal returns of response. In these cases, greater return can be realized by planning around the ineradicable components of human error than by pursuing an obstinate resolution to change the unchangeable. Thus, greater attention is being paid to the development of vehicles which do not permit hazardous behavior or which cushion its consequences when it does occur. Similarly, the driving environment is being designed not only to lower the chance of human error but also to minimize the damage resulting from the accidents that inevitably will take place.

At times, policy levers may be manipulated by the government in order to control those human actions that cause accidents or aggravate resultant harm. Licensing procedures, speed limit signs, traffic signals, and police patrols are examples of such devices which are, among themselves and across various contexts, differentially effective. Ingenuity is being directed toward developing new devices--or toward better exploiting old ones--that will increase governmental leverage upon accident-related behavior.

Nevertheless, it is becoming increasingly realized that attempts to control accidents indirectly by influencing drivers, passengers, and pedestrians are at a comparative disadvantage with respect to more direct governmental actions. Whenever a mode of governmental influence is clumsily designed--so that only in an inefficient way does it reduce accident hazard--it will be resented as an intrusion upon individual freedom. Even the relatively efficient levers of government--such as the speed limit--incur such resentment.

As a result of these factors, a premium is placed upon the simplicity of contemplated governmental actions.[30] The least complicated action is one that may be directly undertaken by the government--for instance the construction of capital improvements to highways. Somewhat more complicated are those actions effected by the government through the actions of private corporations. Examples of such steps would be the mandating of passive internal restraints for automobiles or the establishment of tire manufacture standards or alteration in insurance regulations. In these instances, the responses of but a small number of companies would require monitoring--not a trivial task, but one orders of magnitude easier than enforcing a policy requiring the independent compliance of millions of individuals.

When the appropriate intervention has been decided upon and adopted, care must be exercised to determine whether its effect is thwarted by the adaptive actions of companies or individuals. Suppose for instance that a government wishes to reduce accident injury on a certain stretch of road. A lower speed limit might have the desired effect but would be prohibitively difficult to enforce. Accordingly, the government might take the more expensive direct action of widening the road and separating the opposite streams of traffic with a central median. What may occur is that enough drivers will be encouraged by the presence of the median to increase their speeds that the accident-injury profile remains unaltered. The gain of the median will then be reduced travel times. Yet the cost of the median may not be considered justified by those reduced travel times, but would have been justified by the reduction in injuries had the speeds not risen. This type of behavioral adaptation to change--in this hypothetical case, an unfortuante one--should then be borne in mind for future decisions of a similar nature.

Safety Research

For effective resolution of the road accident situation, the overview of policy analysis and the insights of safety research must be simultaneously applied in a coordinated manner. To achieve a common conceptual perspective for the two disciplines, the following classification of safety research is proposed:

1) Hypothesis generation. We have stressed the need for an inventive, unconstrained search for possible policy remedies to the causes of accidents. Imagination here is essential and is usefully abetted by planned and structured inquiry into the factors involved or interconnected in accidents. Such searches might comprise statistical demographic explorations focusing on accident involvement or non-involvement. Alternatively, in-depth interviews with accident participants might provide valuable clues for potential policy guidance. The immediate object of the searches cannot be firm understanding of accidnet causation, but will instead be identification of plausible hypotheses concerning that causation. The types of hypotheses that might be generated would cover: suggested outlines of personality profiles prone to accidents; indications that certain driver habits, pre-driving activities, or momentary actions during driving lead to accidents; possbile car modifications that might reduce accident damage; and hints that common environmental features are linked to patterns of accident occurrence or severity;

2) Hypothesis confirmation. The generation of hypotheses should be followed by testing to determine their validity. Optimal testing brings into play a battery of procedures which are sequentially employed until adequate information for acceptance or rejection of the hypotheses is obtained. The choice of appropriate test at a given time depends on the current state of knowledge and upon the costs of alternative methods. One should never spend more upon any research trial than the expected informational benefit in policy terms, taking into account the probability that the hypothesis is true and the probability that effective policy actions can take advantage of this knowledge. Generally, the initial test should comprise assessment of already available knowledge and data upon the hypothesis. When a firmer understanding is required before action can be taken or the hypothesis is rejected, the safety researcher must choose among alternative ways of obtaining further information. Laboratory experiments, driving simulations, an interview series, or targeted data-gathering efforts may each in various circumstances represent the most cost-effective way to verify the hypothesis;

3) Policy experimentation. Even before a hypothesis is finally confirmed or rejected, policy experimentation may be undertaken to determine whether its possible validity can be the basis for corrective policy measures. If, for example,

it is suspected that fatigue is a factor in accidents, research might investigate whether various ways of combatting fatigue--perhaps by eating candy to increase blood sugar or by listening to anti-soporific music or by insuring a flow of fresh air--are effective. Other instances of policy experimentation are the actual car crashes with dummy occupants designed to test whether seat belts or air bags can reduce the injuries incurred. In the case of alcohol, the basic hypothesis of its contribution to accidents has been so solidly confirmed that further studies upon the hypothesis are no longer useful. Instead, emphasis should be placed upon inventing and testing out ways for controlling the traffic hazard it poses;

4) Policy evaluation. The only level at which conclusive verfication that a policy is beneficial may be obtained is the assessment of its actual implementation. Thus even if it is shown that candy reduces fatigue or that seat belts limit injury, policies built around these facts are not automatically effective. The candy may not be eaten or the seat belts not fastened. Even if motorists do comply with the policies, they may be sufficiently emboldened by knowledge of their greater security to drive just enough faster that no reduction of accident injury is achieved. The statistically ideal test is through random separation of the population--perhaps by individual, perhaps by locality--whereupon alternative policies are implemented and their effects measured. Unfortunately, the expense of this procedure--in terms of money, time, and procedural complication--often renders it infeasible. When one policy is believed safer, social decision-makers are understandably averse to testing out the apparently less safe alternative. This situation requires that analysts make the most of information becoming naturally available. Changes in policy should be scrutinized over time to see whether they effect improvements in various types of accidents.[31] Municipalities vary in their traffic codes, automobiles are differently engineered, and the traffic environments are not homogeneous. Meticulous examination of these differences may often reveal the effects of various laws, automobile construction, and road planning.[32]

This taxonomy can be illustrated as a system of filters or lenses seeking to derive from the unordered phenomena of the world a focused and effective safety policy. This is depicted in Figure I. On the extreme left are the interconnected but chaotic events and circumstances of the world. It is the task of hypothesis generation--the leftmost lens--to pick out from this amorphous tangle those factors which might be related to the causation or severity of accidents. Only lines corresponding to such elements are transmitted through this filter.

The second lens is that of hypothesis confirmation which tests more rigorously whether the factors originally indentified do, in fact, affect accidents. Those that do not are not transmitted to the third lens of policy experimentation. This

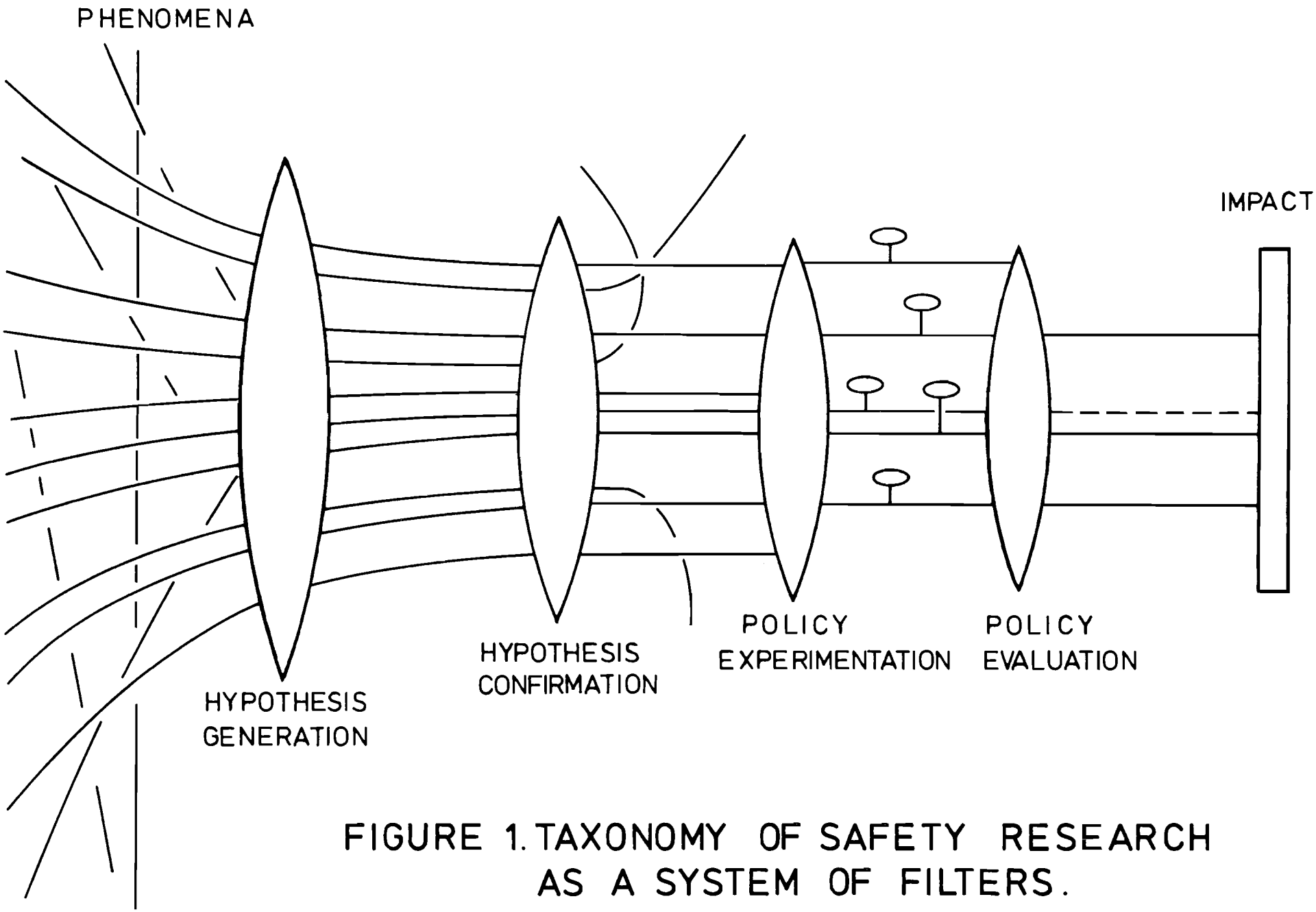

FIGURE 1. TAXONOMY OF SAFETY RESEARCH AS A SYSTEM OF FILTERS.

filter attempts to fashion governmental handles for the manipulation of accident-connected factors. Those factors for which no such handle can be invented do not pass through the third lens.

The fourth and final filter is that of policy evaluation where it is seen that, even among those factors for which policy levers have been devised, many do not have their intended effect. Those that achieve no beneficial policy impact are not passed on by this filter while those achieving substantially less than their intended effect survive only in attentuated form. The latter case is shown by the dotted line second from top. Those lines reaching the final screen of impact represent elements related to accidents which may be efficiently wielded by a society seeking to enhance road safety.

IV. Conclusion

In order to present a policy-oriented overview of safety research, we considered in the second part of this paper obstacles to policy analysis. The third section then formulated the outlines of a strategy for surmounting those obstacles and for redirecting safety research to achieve more effectively policy benefits. The precise details of that strategy could not here be given: 1) because this is an areas whose vast intricacies and uncertainties dwarf our own understanding; and 2) because any attempt to provide an unchanging blueprint for future action would be wrong. Optimal management of safety research is above all a delicate learning process in which the cues for future endeavors must be taken from the forthcoming research results which cannot be foreknown. Such management requires the assimilation of information presently strewn across many institutions. An important first step might therefore be the strengthening and consolidation of this information --taking duly into account the costs of such information acquisition and processing weighed against its ultimate potential benefits. The aim of this paper has been to provide a conceptual basis--that of policy analysis--for judging just how safety research ought to be guided to achieve those benefits.

Footnotes

(Bracketed numbers refer to items in the References.)

[1]A worthy attempt to break out of this trap is given by the Arthur D. Little overview of traffic safety research [3]. Even this review, however, suffers from limited imagination and presents analysis that is, in spots, oversimplified and inadequate.

[2]See, for instance, R. McFarland, "Health and Safety in Transportation," in [2, pp. 77-78], or R. Nader [4, pp. lv-lvii].

[3]See R. Nader [4, pp. 268-278].

[4]See R. Nader [4, pp. 1 and 249-50] for a suggested futuristic solution to this.

[5]The primary role of the courts in traffic safety is that of blame assignment. This may consume excessive resources for unsatisfactory returns.

[6]See S. Hulbert and C. Wojcik in [1, pp. 44-73].

[7]E.g. K. Bjerver and L. Goldberg, "Effect of Alcohol Ingestion on Driving Ability," in [2, pp. 101-106] or J. Cohen, E. Dearnaley, and C. Hansel, "The Risk Taken in Driving Under the Influence of Alcohol," in [2, pp. 351-358].

[8]A. D. Little [3, pp. 56-62] reviews several studies on the effect of fatigue on driving.

[9]Hulbert and Wojcik, op. cit., p. 47.

[10]R. Nader [4. pp. 248-249] discusses this problem.

[11]For a study which discusses this problem and presents data adjusted for exposure, see A. R. Lauer, "Age and Sex in Relation to Accidents," in [2, pp. 130-138].

[12]Reported in A. D. Little [3, p. 121].

[13]W. Haddon et al., "A Controlled Investigation of the Characteristics of Adult Pedestrians Fatally Injured by Motor Vehicles in Manhattan," in [2, pp. 232-250].

[14]E.g. J. Conger et al., "Psychological and Psychophysiological Factors in Motor Vehicle Accidents," in [2, pp. 327-335].

[15]See A. D. Little [3, pp. 106-119].

[16]A study reported in A. D. Little [3, p. 139].

[17]Reported, for example, in R. Nader [4, p. 228].

[18]See A. D. Little [3, pp. 170-171]. These findings were substantiated by the record achieved during 1973-74 when the fuel crisis led to lower speed limits.

[19]A Study reported in A. D. Little [3, pp. 70-71].

[20]Similar findings for cardio-vascular ailments are reported by A. Burg, "Characteristics of Drivers," in [1, p. 85].

[21]See A. D. Little [3, pp. 168-169].

[22]L. S. Robertson et al., "A Controlled Study of the Effect of Television Messages on Safety Belt Use," American Journal of Public Health, Nov. 1974 (64, 11), pp. 1071-1080.

[23]See A. D. Little [3, p. 271] for such findings as one in California that 53.7% of drivers whose licenses were revoked not only continued driving but also were cited for infractions during the period of revocation.

[24]See S. Hulbert, "Effects of Driver Fatigue," in [1, pp. 288-302] or A. D. Little [3, pp. 56-62].

[25]See R. Nader [4, p. 192].

[26]Except insofar as it may lower his liability to others.

[27]R. Nader [4, pp. xxx-xxxii] cites such a study performed under a contract to the State of New York.

[28]This was ironically brought out in the development of the experimental safety vehicle (ESV) described by Rune Andreasson which was built like a tank to protect its own occupants.

[29]A problem not necessarily involving externality effects --and thus not engaging the traditional arguments for governmental intervention--is that of the failure to fasten safety belts. Since the negative consequences might be totally borne by the car occupant making this decision, it might be argued that he alone should decide whether or not--for a given trip--to wear the belt. The government role would be limited to publicizing relevant information on the safety increment provided by safety belts and to legislating insurance provisions making the occupant the true bearer of risk. Such provisions might lower insurance premiums for drivers pledging always to wear safety belts--or to pay their own medical expenses if involved in an accident without a fastened belt. Certain governments, however, have decided that car occupants should be protected from their own obtuseness in preferring not to wear installed safety belts and have made their use mandatory.

[30]A spectacular example where the simplicity of an action outweighs all the theoretical advantages of equity attributed to its alternatives is that of no-fault automobile insurance.

[31]As we have argued above, attention also should be paid to the danger that certain types of accidents are being reduced at the expense of increases in other accident categories.

[32]Another research category important to safety but falling outside our matrix is that of design research. It encompasses such activities as determining interior car outlay, sign placing and coloring, and integration of roads with the urban environment. Certain of its concerns will fall within the research types described in the text. Thus, the placing of instrument knobs may be determined to be an important factor in accident injuries and as such be studied in detail. The reasons for separating design research from our basic taxonomy are twofold: 1) design must take into consideration many factors--such as esthetics, or the demands of urban systems--not directly related to road safety; and 2) many factors with which it deals--such as the colors of sign lettering--are only tenuously related to accident rates.

References

[1] Forbes, T. Ed. Human Factors in Highway Traffic Safety Research. New York, Wiley, 1972.

[2] Haddon, Jr., W., Suchman, E., and Klein, D. Accident Research. New York, Harper & Row, 1964.

[3] Little, Arthur D., Inc. The State of the Art of Traffic Safety. 1966.

[4] Nader, R. Unsafe at Any Speed. New York, Bantam, 1973.